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Preliminary Assessment of Modular Waste-to-Energy Technology as an Energy Source for the W. E. Swoope Steam Plant New Smyrna Beach, Florida

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Prepared for

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January 1981

Solid Waste

EPA

A TECHNICAL ASSISTANCE PROGRAM REPORT

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REPRODUCED BY
NATIONAL TECHNICAL
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Technical assistance by personnel teams. 42 USC 6913

RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panels") to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

This report has been reviewed by the Project Officer, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Project Officer: Elmer G. Cleveland

U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL ASSISTANCE PROGRAM REPORT SERIES

PRELIMINARY ASSESSMENT OF MODULAR WASTE-TO-ENERGY TECHNOLOGY AS AN ENERGY SOURCE FOR THE W.E. SWOOPE STEAM PLANT NEW SMYRNA BEACH, FLORIDA

PREPARED FOR

OFFICE OF SOLID WASTE MANAGEMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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BY

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JANUARY 1981

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PREFACE

This report was prepared for the City of New Smyrna Beach, Florida, under the Technical Assistance and Panels Program, which is conducted by the U.S. Environmental Protection Agency (EPA) to provide assistance to state and local governments. Technical assistance was provided in response to a request for assistance in the area of solid waste submitted to U.S. EPA Region IV by New Smyrna Beach.

This report presents the results of a preliminary assessment of the feasibility of resource recovery, in particular a low-Btu hot gas system, as a means of displacing natural gas used in the city's electricity generating plant. This work involved assessing the technical feasibility of three waste-to-energy concepts under various assumptions of waste throughput and utility boiler operating levels. In addition, study-level economic estimates were developed. The final aspect of this preliminary feasibility assessment involved identifying the major tasks to be performed by the city and the Utilities Commission prior to their deciding to implement a resource recovery project. These activities reflect the results of three site visits to New Smyrna Beach by CSI Resource Systems, Inc. (Resource Systems); and discussions with city officials and personnel from the Utilities Commission, City of New Smyrna Beach, Florida.

Resource Systems is a technical assistance contractor to the Office of Solid and Hazardous Waste, U.S. EPA Region IV. Under the terms of the Technical Assistance and Panels Program, all of Resource Systems' technical assistance activities on behalf of New Smyrna Beach were paid for by EPA.

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OVERVIEW

The City of New Smyrna Beach is a resort community of approximately 17,000 people, located on the east coast of Florida, 15 miles south of Daytona Beach. The city generates approximately 42 tons of solid waste per day on a 7-day-per-week basis (TPD_7).[1] New Smyrna Beach operates a refuse collection system and a transfer system. Collection vehicles bring the waste to the city's transfer station, and transfer vehicles then haul the waste 21 miles, to the Volusia County landfill on Tomoka Farm Road.

City officials feel that this transfer and disposal arrangement is not satisfactory, for several reasons. First, the cost of hauling waste to the county landfill is high and will increase as fuel prices continue to rise. Second, the city expects landfilling costs to rise significantly from their current level of around $15 per ton. Third, the long-term availability of this county landfill is uncertain. Although the county has recently acquired additional acreage adjacent to the landfill and plans to expand the fill both horizontally and vertically, the city is uncertain whether the county will be able to comply with increasingly stringent environmental regulations for landfills, given the landfill's proximity to groundwater recharge areas. Finally, city officials recognize that each ton of solid waste has an energy content roughly equivalent to 63 gallons of oil. They therefore believe that the waste should be put to productive use, rather than buried in the land.

Because of these concerns, the city become interested in an unsolicited proposal by a system vendor to produce a low-Btu hot gas in the primary chamber of a starved-air modular combustion unit

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1. Russell & Axon, Engineers-Planners-Architects, Inc., Solid Waste Incineration Feasibility Study, prepared for the City Commission of New Smyrna Beach, Florida, Project No. 666-771-02, 1977. This estimate has not been verified through a weighing program; nor has it been updated.

(MCU). This hot gas would be used to displace some of the fossil fuel now being burned in the W.E. Swoope Steam Plant, a 7.5-megawatt (MW) electric generating station owned and operated by the Utilities Commission, City of New Smyrna Beach, Florida (hereafter referred to as the Utilities Commission). The plant boiler has a dual-fuel capability (oil and natural gas). Currently, it is fired by natural gas. This plant is currently operated as a peaking station. The Utilities Commission has, however, indicated that it would prefer to operate the plant as a baseload station. In addition to this plant, the Utilities Commission owns and operates a diesel plant and owns a portion of Florida Power Company's Crystal River 3 nuclear plant. The Utilities Commission purchases power to meet the remainder (roughly one-half) of the electricity demand in New Smyrna Beach. The majority of the purchased power comes from Florida Power & Light (FP&L) and is produced primarily by oil-fired units (a smaller portion of the purchased electricity is produced by coal-fired and nuclear units).

To assess the feasibility of implementing resource recovery, in particular the proposed low-Btu hot gas system, as a means of displacing natural gas used by the W.E. Swoope Steam Plant, the mayor of New Smyrna Beach requested technical assistance from EPA through its Technical Assistance and Panels Program.

The analysis of the waste-to-energy concept had two overall objectives. Its primary purpose was to make a preliminary assessment of the technical and economic feasibility of implementing an MCU-based resource recovery system to supply energy, in particular low-Btu hot gas, to the W.E. Swoope Steam Plant. The capital and operating and maintenance cost estimates developed in this study indicate a rough order-of-magnitude only. They are not based on detailed engineering or design work or written bid quotations from vendors in response to plant specifications. In addition, the capital cost estimates are exclusive of costs associated with modifications at the steam plant. Likewise, the energy revenue estimates, the net disposal costs of resource recovery, and the projected landfill disposal costs indicate order-of-magnitude only. If, on the basis of this preliminary assessment, the waste-to-energy concept appeared feasible, the second objective was to identify the next

steps that the city should perform before making a final decision to commit significant additional resources to a comprehensive feasibility study.

Three alternative applications of MCU waste-to-energy technology, including the production of low-Btu hot gas, were identified as worthy of consideration. For each alternative, a preliminary feasibility assessment was made. The alternatives assessed are:

1. Production of low-Btu hot gas to be burned as a supplemental fuel in the existing boiler of the steam plant, assuming the plant is baseloaded.

2. Production of saturated steam to be superheated in the existing boiler of the steam plant and used to generate baseload electricity.

3. Production of saturated steam to be converted directly to baseload electricity in a new turbine-generator that is capable of using low-pressure steam.

All three alternatives appear to be technically feasible under certain operating conditions. However, even under the most favorable assumptions regarding plant sizing, economics, and the implementation time frame, the estimated first-year net disposal costs for the MCU-based alternatives are higher, in some cases significantly higher, than the projected 1983 cost to the city of its current landfill disposal option.* The estimated increase in solid waste disposal costs with resource recovery ranges from $9 to $57 per ton of waste depending on the assumed waste throughput and the energy product from the waste. This disposal cost increase would occur with no attendent cost decrease for New Smyrna's electric ratepayers. The economics appear to be the most favorable for a 150-TPD_7 low-Btu hot gas system.

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* Order-of-magnitude economic estimates were developed under various waste throughput assumptions and under two energy pricing scenarios: (1) DOE middle-case forecasts and (2) natural gas price escalation at the same rate as electricity costs.

In part, the estimated early-year economics are unfavorable, because waste-derived electricity can best compete with electric utilities when resource recovery system sizes are greater than 1,500 TPD. Typically, waste-to-energy plants with smaller waste throughputs provide more favorable economics when producing such products as process steam for industrial applications. This general finding appears to hold true in New Smyrna as well. Moreover, in the case of the W.E. Swoope Steam Plant, the value of the low-Btu hot gas is lower than might otherwise be the case for displacement of natural gas, because total per-kWh production costs at the plant have to be equal to or less than the price of electricity purchased from FP&L. In addition, it is noted that the cost avoidance value of electricity under the Public Utility Regulatory Policies Act (PURPA) regulations does not appear to be applicable to a New Smyrna Beach resource recovery project. This occurs because the city is producing waste-derived electricity for its own use, rather than for sale to another utility.

Even though early-year economics may be unfavorable, resource recovery economics can improve over time relative to landfill disposal costs because energy revenues can realistically be expected to increase at the same or at a greater rate than the cost of owning and operating the facility. Consequently, consideration of life-cycle economics is important. While, net disposal cost estimates for the resource recovery options were only projected for the first 6 years of plant operations, it can be presumed that they could become more favorable for the balance of a project's life in New Smyrna Beach. The 150-TPD_7 low-Btu hot gas system is the only waste-to-energy alternative evaluated that has an estimated net disposal cost that is comparable to the projected cost of landfill disposal in 1988 (the assumed 6th year of full-scale resource recovery facility operations). If energy costs continue to escalate at a higher rate than ownership and operating costs, it is reasonable to assume that, when considered on a life-cycle-cost basis, the resource recovery facility could provide favorable economics.

However, this alternative assumes that more than two-thirds of the waste needed to supply the facility can be acquired from neighboring communities. The success of this facility depends on obtaining long-term waste delivery commitments for this additional tonnage. As the projected first-year disposal charge at the recovery facility would be almost 40 percent higher than the projected 1983 cost of landfill disposal, at issue is whether other communities would be willing to commit to delivery of their wastes to this facility so long as a lower priced landfill disposal option were available.

If the city wishes to continue its investigation of resource recovery, it should attempt to resolve this critical issue of waste capture and other major issues related to a 150-TPD, low-Btu hot gas system prior to committing significant resources to a detailed feasibility study. More specifically, the city should:

- Implement a weighing program at the Volusia County landfill to develop a more reliable estimate of waste generation.

- Initiate discussions with Port Orange and/or other nearby communities to ascertain their interest in delivering waste to a resource recovery facility located in New Smyrna. If Port Orange or other communities are interested, have them institute weighing programs (if they do not already do so) to develop estimates of their waste generation.

- Monitor transfer and landfill disposal costs and landfill availability. As costs increase and/or landfill capacity decreases, resource recovery will become a more economically competitive option.

- Hold meetings with the Utilities Commission and the public to ascertain the overall benefits to the electric ratepayers of baseloading the Swoope plant using waste-derived energy as a supplemental fuel. Then, compare the benefits to the ratepayers to the waste disposal costs and/or benefits to the general taxpayer in order to gain an understanding of what cost/benefit trade-offs can reasonably be made.

If, as a result of these activities, the low-Btu hot gas system looks promising, the city should contract with an engineering consultant to undertake a detailed engineering study. At a minimum, the detailed study should include the following tasks:

- Assess the consequences on power plant performance of erratic energy content of low-Btu gas.
- Prepare a conceptual design of a burner that can fire low-Btu gas and natural gas simultaneously.
- Evaluate the flow characteristics of the low-Btu gas to the burner.
- Calculate the required fan capacity and determine if a replacement is needed.
- Evaluate the expected temperature distribution in the burner.
- Calculate the heat rate for combined fuel firing.
- Assess the fouling characteristics of sodium fumes entrained in the low-Btu gas.
- Recommend a location for the gasifier.
- Estimate heat loss through low-Btu gas ductwork.
- Develop a conceptual design to accommodate large-diameter low-Btu gas piping in the existing burner structure.
- Estimate the capital cost of necessary power plant modifications.

If, as a result of this investigation, resource recovery in the City of New Smyrna does not appear to be practical and the city still wishes to pursue resource recovery as a solid waste management option, it could investigate the feasibility of delivering its waste to the resource recovery facility currently in procurement planning in Daytona Beach. It is unlikely that the waste hauling distance

would be prohibitive, as the proposed Daytona Beach facility is only a few miles further than the Volusia County landfill. Investigation of this possible option was beyond the scope of this feasibility study.

In the following sections of this report, greater detail is provided on the approach taken in this study and the results of the evaluation of alternatives. A discussion of the technical aspects of the alternatives is presented in Appendix A. In Appendix B, a methodology for estimating system costs for the low-Btu gas alternative is given. Appendix B also contains order-of-magnitude economic estimates for this alternative and for the production of saturated steam to drive a new low-pressure turbine-generator (Alternatives 1 and 3).

APPROACH

The preliminary assessment of technical and economic feasibility involved identifying and analyzing several MCU-based resource recovery technologies. Previous experience has suggested that an MCU system sized for a throughput of 100 TPD_7 would likely be the smallest economically practical system. Because only 42 TPD_7 of waste are estimated to be generated in New Smyrna Beach, the remaining waste required to achieve this throughput would have to be obtained from nearby communities. The availability of waste from these communities is uncertain; consequently, a system sized for 50-TPD_7 throughput was also considered for each of these alternatives. In addition, a 150-TPD_7 system was assessed for the low-Btu hot gas alternative to indicate the effect of a larger sized system on project economics.

MCU systems can be used to produce low-Btu hot gas, saturated and slightly superheated steam, and electricity. An assessment was initially made of the feasibility of using an MCU-based system to supply either low-Btu hot gas or saturated steam for superheating to the W.E. Swoope Plant under its current peaking operating conditions.[2] However, because solid waste is generated continuously, an MCU must be operated continuously or the waste must be disposed of in the landfill. In other words, for purposes of reliable solid waste disposal, the MCU must be operated as a baseload unit. Moreover, MCUs must operate continuously for reasonably long periods of time (i.e., several days), because startup and burndown times are significant for these units. Also, at any given time, the MCU primary chamber contains sufficient fuel to burn for 1 to 3 hours; hence, it is difficult for the MCU-generated energy supply to respond to the demands of a peaking boiler, which is typically operated at

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2. See "Evaluation of Modular Waste-To-Energy Technology as an Energy Source for the W.E. Swoope Steam Plant, New Smyrna Beach, Florida," draft report prepared for the City of New Smyrna Beach by CSI Resource Systems, Inc., September 1980.

partial load and shut down at random intervals. Consequently, if the utility boiler were a peaking unit, a portion of the energy output of the MCU system would be wasted, resulting in a highly impractical system.

Because the Utilities Commission has indicated a desire to shift operations at the W.E. Swoope Plant from peaking to baseload, preliminary technical and economic feasibility was assessed for three baseload waste-to-energy alternatives, including the production of low-Btu hot gas. Each alternative is based on MCUs, which are factory-assembled, starved-air combustion units that can burn unprocessed municipal solid waste. These units are being used successfully in several areas of the country to convert small quantities of solid waste (generally 100 TPD) to energy. The output of these systems is typically low- to moderate-pressure steam for industrial process applications.

1. Producing Low-Btu Hot Gas to be Burned in the Utility Boiler. This alternative involves installing an MCU system with several modules and burning waste in the first chamber of each module. The atmosphere of this chamber has insufficient oxygen for complete combustion of waste; the resulting partial combustion of the waste produces a hot combustible low-Btu gas (mostly carbon monoxide and hydrogen). When this hot gas leaves the first chamber, it is introduced directly into the utility boiler through a low-Btu gas burner, as a substitute for a portion of the natural gas used in the boiler. Low-Btu hot gas has been tested as a boiler fuel; however, no known applications use MCU-generated low-Btu gas.

2. Producing Saturated Steam to be Superheated in the Utility Boiler. This alternative involves using an MCU system to raise saturated steam at a sufficient pressure that it can be introduced directly into the utility boiler's superheater and then raised to turbine throttle temperature. Because of pressure losses in the transmission line and in the superheater itself, steam must be generated at around 700 psig to meet the utility's requirement for 625-psig steam. It is theoretically possible for an MCU system

to generate 700-psig saturated steam. Although this capability has not been demonstrated in the field, the enthalpy of the saturated steam is about the same as that usually raised by MCUs, and the required temperature associated with this pressure level is 505 F, only 100 F more than that routinely generated by MCUs. Hence, this application is believed to be feasible.

3. Producing Saturated Steam for Direct Conversion to Electricity. This alternative involves producing saturated steam in an MCU system and installing a new condensing turbine-generator set with appurtenances to use this steam to generate electricity. Essentially, this alternative is a straightforward application of MCU technology as the core element of a new waste-fired electric generating unit. Although turbine-generator sets have not yet been coupled with MCUs, the long-term demonstrated ability of low-pressure steam turbines to drive generators minimizes the technical risks of coupling these two technologies.

ASSESSMENT OF ALTERNATIVES

In this section, the results of the preliminary assessment of the three alternatives are described. A more detailed discussion of the basis for the technical results is presented in Appendix A. In Appendix B, the economic results are presented in more detail. Because Alternative 3 (producing saturated steam for use in a new low-pressure turbine-generator) involves the relatively straightforward application of available technology, the analysis of this alternative focused on its economic practicality for New Smyrna Beach.

1. PRODUCING LOW-BTU HOT GAS

The technical feasibility assessment of this alternative involved analyzing the characteristics of power boilers, as a basis for setting minimum criteria for the energy content of the low-Btu hot gas. Equilibrium chemical thermodynamics was used to predict the characteristics of the hot gas produced in the primary combustion chamber of an MCU. Then, the minimum requirements for effective use of this gas in a utility boiler were defined, and a determination made of whether a system in New Smyrna Beach could meet these minimum conditions.

Previous research indicates that a fuel mixture must have a hot gas heating value above 300 Btu per standard cubic foot (SCF) to avoid derating the boiler and reducing the electricity output of the power plant.[3] The low-Btu hot gas supply must respond to boiler demand fluctuations and must not corrode the boiler. An additional constraint to use of low-Btu gas is the large gas pipe required to deliver the gas into the boiler. For example, 100 ft^3 of gas containing 100 Btu per SCF has the same total energy content as 10 ft^3 of gas containing 1,000 Btu per SCF, but occupies 10 times the volume. It may be difficult for some existing boilers to accommodate the large pipe without structural modifications. It was

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3. Electric Power Research Institute, Low-Btu Gas Study, prepared by Babcock & Wilcox, EPRI 265-2, January 1976.

beyond the scope of this preliminary feasibility study to investigate the practicality of introducing a large gas pipe in the upper story of the steam plant.

The physical and chemical properties of the low-Btu hot gas produced in the primary chamber of an MCU were then predicted. (See Appendix A for a discussion of the assumptions and methodology used in this prediction.) The heating value of the hot gas is estimated to be between 80 and 100 Btu per SCF. Hence, this gas must be blended with another fuel to reach the 300-Btu criterion. The Swoope plant's current fuel, natural gas, has a heating value of 1,000 Btu per SCF and can be blended with low-Btu hot gas to produce a mixture with an acceptable heat content. This mixture clearly has value as a fuel. Moreover, the low-Btu hot gas is generally devoid of fouling elements and contains much less than stoichiometric amounts of sulfur and chlorine. Previous experience indicates that the low-Btu gas will pose no threat of boiler corrosion. Consequently, producing low-Btu hot gas for use in a utility boiler appears to be technically feasible.

To satisfy technical requirements and to utilize the continuous flow of low-Btu hot gas produced by the MCU system, the W.E. Swoope Plant would have to operate continuously at 40 percent of its rated capacity, or 3 MW. In this manner, a mixture of low-Btu gas and natural gas could be used as a baseload fuel to produce electricity.

Rough order-of-magnitude estimates of capital and operating and maintenance costs and energy revenues were developed for a 50-TPD_7, a 100-TPD_7, and a 150-TPD_7 low-Btu gas system, using engineering assumptions derived from previous work on similar sized projects. Economics were estimated for 1983 and 1988, the assumed 1st and 6th years of full-scale resource recovery plant operations. Capital cost estimates were based on a review of recent bid quotations contained in responses to various solicitations for resource recovery projects of similar design capacities and technologies. Capital cost estimates

are exclusive of the capital costs associated with modifications at the W.E. Swoope Steam Plant; it is not known whether these costs would be substantial. Operating and maintenance cost estimates include labor, utilities, maintenance, and disposal of residues and bypassed wastes, and are assumed to escalate at an annual rate of 8 percent. The low-Btu hot gas would be priced at an amount equal to the cost of the electricity that is produced if it were purchased from FP&L, minus the cost of the natural gas required to supplement the low-Btu hot gas. The electricity purchase offset was estimated on the basis of FP&L's 1977 rate of 28.11 mills per kWh, escalated at an annual rate of 12.5 percent through 1985, and at an annual rate of 9.5 percent thereafter.[4] Two energy pricing scenarios for natural gas were used: (1) DOE middle-case forecasts, where the price of gas escalates at 22.8 percent per year to 1985 and 15.7 percent thereafter; and (2) natural gas escalation at the same rate as electricity costs, or 12.5-percent per year escalation through 1985, and 9.5-percent annual escalation thereafter.

The results of the economic analysis are summarized in Appendix B. Even under the most favorable technical and economic assumptions, solid waste management costs would rise substantially with the 100-TPD_7 low-Btu hot gas system and dramatically with the 50-TPD_7 system relative to the projected cost of landfill disposal.

When the system size is increased to 150-TPD_7, resource recovery becomes more competitive with landfill disposal, particularly when considered in terms of life-cycle costs. Assuming that natural gas prices escalate at the same rate as electricity costs, the Utilities Commission could pay around $1.2 million in 1983 and $2.0 million in 1988 for the low-Btu gas produced by a 150-TPD_7 system without raising electrical rates over the cost of purchased power. When the value of the low-Btu hot gas is subtracted

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4. R.W. Beck and Associates, Triennial Report for Fiscal Years Ended September 30, 1975, 1976, and 1977, prepared for the Utilities Commission, City of New Smyrna Beach, Florida.

from the costs associated with owning and operating a recovery plant, net disposal costs are estimated at almost $1.4 million in both 1983 and 1988. This represents a net disposal charge, or tip fee, to the participating communities of about $28 per ton through the first 6 years of full-scale plant operations. Competing transfer and landfill disposal costs are estimated to be around $19 per ton in 1983, increasing to $28 per ton in 1988, at an assumed annual inflation rate of 8 percent.* In other words, implementation of this alternative would result in an estimated disposal cost increase to the taxpayers of around $440,000 in 1983, with no corresponding reduction for the electric ratepayers. By the assumed 6th year of operation, 1988, however, this 150-TPD_7 system could be competitive with the cost of the landfill disposal alternative.

While the 150-TPD_7 low-Btu gas system could become competitive with landfill disposal costs in later operating years and become economically favorable on a life-cycle-cost basis, the early-year costs do not appear to be competitive. At issue is whether or not communities would be willing to deliver their wastes to a 150-TPD_7 facility in New Smyrna Beach if they could continue to landfill their wastes at a lower cost. This issue is of critical importance because successful implementation is dependent on securing long-term delivery commitments from outside jurisdictions for more than two-thirds of the required waste. However, the potential cost impediment to securing the required tonnage could be eliminated if transfer and disposal costs were to increase substantially over those projected for the next few years, and/or regional landfill capacity became a critical problem.

2. PRODUCING STEAM FOR SUPERHEATING IN THE UTILITY BOILER

The technical feasibility assessment of producing steam to be superheated in the boiler of the steam plant involved examining the capabilities of waste heat boilers that can be fitted to MCUs;

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* Landfill disposal costs could escalate at a different, perhaps higher, annual rate than the 8 percent that was assumed. Appendix B presents a methodology for estimating system costs for the low-Btu hot gas alternative. The effects of changes in the escalation assumptions used in this analysis can be assessed by using this methodology to estimate costs under different assumptions.

identifying the requirements for using the existing utility boiler as a separately fired superheater for MCU-generated steam; and determining the operating requirements of such a configuration. The investigation included conversations with the manufacturer of the steam plant boiler, as well as with the manufacturers of waste heat boilers.

The conclusion of this assessment is that this alternative appears technically feasible at a 50-TPD_7 and a 100-TPD_7 throughput. While the scope of this study did not call for assessing this alternative at plant sizes greater than 100 TPD_7, it may also be technically feasible to use the saturated steam produced by a 150-TPD_7 system. A waste heat boiler can be manufactured to produce saturated steam at a sufficient pressure (700 psig) to be superheated in a power boiler similar to that used at the steam plant in New Smyrna Beach and meet the utility's requirement for 625-psig steam after accounting for pressure losses. The necessary piping can be installed to introduce the saturated steam into the plant's existing superheater and boiler. However, the power boiler must be operating continuously at a certain percentage of full load before accepting supplemental steam, in order to prevent damage to furnace wall tubes from overheating. For the boiler at the W.E. Swoope Steam Plant, the minimum operating criterion to prevent such damage is about 50 percent of rated capacity, or 3.75 MW.

The preliminary economic assessment that was performed for the 50- and 100-TPD_7 low-Btu hot gas alternatives provided a basis for considering the economic viability of this resource recovery alternative. Without generating economic estimates for this alternative, it was possible to determine that the economics would be somewhat less favorable than the low-Btu hot gas case for the following two reasons:

1. Throughout most of the year, the W.E. Swoope Plant is not on economic dispatch; i.e., most of the time, it is less expensive to purchase electricity than it is to produce that amount of electricity in the gas-fired plant. As the Swoope plant would have to operate at 50-percent of its rated capacity (3.75 MW), rather than at 40 percent (3 MW) as would be required

in the low-Btu gas case, more natural gas would have to be used. This increased usage would result in a lower price for the steam supplied by the resource recovery plant. Consequently, the costs of owning and operating the resource recovery system would be higher as there would be less revenues to offset these costs.

2. The waste heat boiler that would be coupled with the MCU facility is less efficient than the W.E. Swoope Plant boiler. Therefore, the net energy efficiency of this MCU system alternative would be less than with the low-Btu gas alternative. As less energy would be produced, energy revenues would be reduced further.

3. PRODUCING ELECTRICITY FROM SATURATED STEAM WITH A NEW TURBINE-GENERATOR

Because this alternative is a relatively straightforward application of existing MCU and electricity generation technology, the evaluation focused on economic, rather than technical, considerations. Waste-fired electricity generation at a waste throughput of less than 1,500 TPD_7 normally has difficulty competing with landfill disposal alternatives because energy revenues (a critical factor in the economic viability of a recovery project) are often not as great as revenues from other waste-derived products, such as process steam that is sold to industries. In the case of a project in New Smyrna Beach, economic competitiveness becomes even more problematic because generating electricity from saturated steam is inherently inefficient. Typically, only 15 to 20 percent of the Btu content of the solid waste is actually converted to electricity. In a typical high-temperature power plant, on the other hand, 30 to 35 percent of the available energy is converted to electricity.

The cost of an MCU-based electricity generating plant (50 or 100 TPD_7) would be borne by the taxpayers through a solid waste tip fee. A rough order-of-magnitude projection of this cost was developed, using information from analyses of projects of similar size and technologies to determine whether the tip fee might be

competitive with the current system of transferring waste generated in New Smyrna Beach to the Volusia County landfill. The tip fee was projected by adding annualized system capital costs to annual operating costs and subtracting revenues that would be realized from the sale of electricity at the rates currently being paid by the New Smyrna Beach Utilities Commission for power purchased from the grid.

The tip fee projected for a 100-TPD_7 waste-to-electricity system in 1983 is $55 per ton, which is much higher than the projected 1983 cost of $19 per ton for the existing disposal system. For the smaller, 50-TPD_7 system the tip fee would be even higher. Therefore, unless economic conditions change significantly or the existing disposal system becomes impractical, this alternative is not likely to be economically feasible for the City of New Smyrna Beach. Moreover, it is unlikely that neighboring communities would be willing to deliver their wastes to a resource recovery facility with such high, noncompetitive tip fees.

APPENDIX A.
TECHNICAL DISCUSSION
OF WASTE-TO-ENERGY ALTERNATIVES

This appendix presents a discussion of the technical aspects of the following three MCU-based waste-to-energy alternatives for the City of New Smyrna Beach:

1. Producing low-Btu hot gas to be burned in the boiler of the W.E. Swoope Steam Plant.
2. Producing saturated steam to be superheated in the boiler of the steam plant.
3. Producing saturated steam for direct conversion to electricity in a new low-pressure steam turbine-generator.

In the following sections, each of these alternatives is discussed.

1. TECHNICAL FEASIBILITY OF PRODUCING A SUITABLE LOW-BTU HOT GAS

For many years, materials similar to solid waste, such as peat and lignite, have been successfully gasified to produce industrial fuel. If solid waste can be economically and reliably gasified to produce a suitable boiler fuel, substantial capital cost advantages can be realized by using existing firing and energy recovery equipment. Development work for the Baltimore Landgard plant[1] and the Andco-Torrax pilot facility in Tonawanda, New York,[2] indicates that air-blown solid waste gasifiers produce a hot gas with a heat content of approximately 100 Btu per SCF.

Because the primary chamber of an MCU is operated under substoichiometric firing conditions, this chamber is a solid waste

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1. U.S. Environmental Protection Agency, A Technical and Economic Evaluation of the Project in Baltimore, Maryland, Vol. 3, USEPA SW-175C.3, 1979.

2. J. Z. Stoin, Torrax: A Slagging Pyrolysis System for Converting Solid Waste to Fuel Gas, Carborundum Environmental Systems, Inc.

gasifier and produces a potentially usable low- to medium-Btu hot gas. This approach is attractive, because the technology required is readily available and proven. Purchasing only the MCU primary chambers and using existing boilers and turbine-generators further increases the attractiveness of the approach by making use of an existing capital investment. In addition, the power cycle used is more efficient than that of a low-pressure steam power system.

Conditions for Use

Two major conditions are necessary for this alternative to be considered viable: continuous operation and adequate gas heat content.

A gasifier for solid waste must operate as a baseload unit, because solid waste is generated continuously and must be processed. In addition, the mechanical reliability and load-response characteristics of MCUs require continuous, baseload operation. Therefore, the utility boiler connected to the gasifier should also be baseloaded, so that it can utilize all of the gas produced by the MCU.

Research conducted by boiler manufacturers indicates that when gas- and oil-fired utility boilers are retrofitted to use low-Btu hot gas, they are usually derated unless the gas has a heat content of at least 300 Btu per SCF.[3] The research also points to several issues that must be considered when evaluating the performance characteristics of a utility boiler firing low-Btu hot gas. First, the size of the pipes or ducts handling the fuel increases rapidly as the heating value falls below 300 Btu per SCF, because the volume of a fuel is inversely proportional to its Btu content. For example, 100 ft^3 of gas containing 100 Btu per SCF has the same total

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3. Electric Power Research Institute, Low-Btu Gas Study, prepared by Babcock & Wilcox, EPRI 265-2, January 1976.

energy content as 10 ft^3 of gas containing 1,000 Btu per SCF but occupies 10 times the volume. It may be very difficult to route such large pipes or ducts in an existing facility. At MCU production temperatures of 1400 F, the hot gas duct from a 50-TPD MCU must be approximately 1.75 feet in diameter if the gas velocity is approximately 80 feet per second. Routing a duct of this size to the face of the boiler in the W.E. Swoope Steam Plant would probably require structural modification of the turbine building.

Second, using existing gas burners at the Swoope plant may present a problem. These burners can usually be converted with minor modifications to handle gas containing at least 300 Btu per SCF. For a very low-Btu gas, however, it is necessary to use burners similar to the carbon monoxide burners used in refineries, which have much larger throats than the existing gas burners. Installation of such burners would require front face modifications to the boiler tube wall at the W.E. Swoope Steam Plant.

Third, using very low-Btu hot gas is existing boilers changes the pattern of heat absorption in the furnace/boiler, because of the greater volume of flue gas, the reduced flame temperature, and the altered hot gas emissivity. Burning a fuel containing 100 Btu per SCF produces more than 50 percent more flue gas than burning natural gas or oil. This greater volume of flue gas both increases mass flow through the boiler and reduces peak flame temperature. Because the rate of heat transfer in the various sections of a boiler is affected by the quantity and temperature of flue gas, a change in either of these properties will alter the distribution of heat transfer within the boiler. Radiant absorption in the furnace decreases as heating value decreases below 300 Btu per SCF, whereas radiant absorption and convective transfer in the superheater may considerably exceed design levels for this unit. In addition, the greater volume of flue gas sharply increases the draft losses through the furnace, convection pass, and air preheater. These increased losses may require extensive mechanical and structural changes to the unit before it can operate at design rating. Increased flue gas velocities may also cause vibration or noise in the unit.

Finally, the larger volumes of flue gas also cause a reduction in overall unit efficiency (a reduction of approximately 8 percent was documented in one study). This reduction results from the increased mass flow entering the air preheater and stack. Some of the extra heat in the flue gas is not absorbed as it passes through the air preheater, which increases dry gas stack losses.

Analysis of the Alternative

To analyze the technical feasibility of producing low-Btu hot gas for use in utility boilers, it was necessary to determine the composition and heating value of the gas exiting the primary chamber of an MCU. So far as is known, the gas leaving an MCU primary chamber has never been directly sampled and analyzed; hence, an analysis using equilibrium chemical thermodynamics was conducted to determine the composition and heating value of MCU-generated gas. The analysis is based on MCU operating data acquired during the testing of an MCU facility in North Little Rock, Arkansas, by Systems Technology Corporation for EPA in October 1978,[4] and on a related report prepared by CSI Resource Systems, Inc.[5] In these evaluations, it was observed that, when the MCU was operating properly, a temperature of approximately 1300 to 1400 F was indicated by an uncalibrated thermocouple near the exit of the primary chamber. When the MCU was operating with 104-percent excess air at the afterburner outlet, the flue gas temperature reached 1800 F. Elemental waste composition and heat content were also determined for solid waste as received. Hence, available data were sufficient to determine air flow to the primary chamber by examining predicted flame temperature

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4. Systems Technology Corporation, Small Modular Incinerator Systems with Heat Recovery: A Technical, Environmental, and Economic Evaluation, USEPA SW-177C, November 1979.

5. CSI Resource Systems, Inc., Witnessing Report for the Third EPA-Sponsored North Little Rock Facility Test, November 1978.

and to check the data manipulations by comparing afterburner outlet temperatures using known excess air levels.

The equilibrium chemistry of the gas was estimated using the Gordon and McBride computer code, developed by the National Aeronautics and Space Administration.[6] This code uses minimization of free energy techniques. Data on combustion properties of chemical compounds were taken from the JANAF Thermochemical Tables.[7] The program was used to generate profiles of equilibrium gas temperature, composition, and hot gas heat content over a range of quantities of combustion air, from 50 percent of theoretical air to 100-percent excess air. The computed hot gas heat content includes the residual heat of combustion, which could be obtained if the gas were burned to completion with excess air, as well as the sensible heat resulting from the elevated reaction temperature. Only gas species present in concentrations greater than 10 parts per million (ppm) were reported, although the code uses compounds present in concentrations of 0.1 ppm in computing temperature and composition.

On the basis of this analysis, it was determined that an MCU primary chamber yields a gas with a heat content of approximately 90 Btu per SCF when the chamber is operating at 55 percent of theoretical air (-45 percent excess air) and at 1400 F. This value is substantially below the required level of 300 Btu per SCF for operating an unmodified oil or gas boiler and would lead to a significant derating of the existing unit (see Figure 1). Figure 2 presents, in mole fractions, the equilibrium composition of the major combustion products present in the low-Btu hot gas, over the range of excess air levels considered. These fractions were used to estimate the fuel value of the gas produced in the primary chamber.

Figure 3 shows, as a function of boiler rating, the average heat content of the low-Btu gas/natural gas mixtures that would be fired

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6. Sanford Gordon and Bonnie McBridge, "Computer Program for Calculation of Complex Chemical Equilibrium Compositions, Rocket Performance, Incindent and Reflected Shocks, and Chapman-Joquet Detonations, NASA SP-273, 1973.

7. JANAF Thermochemical Tables, Dow Chemical Company, Midland, Michigan, December 31, 1960 to June 30, 1970.

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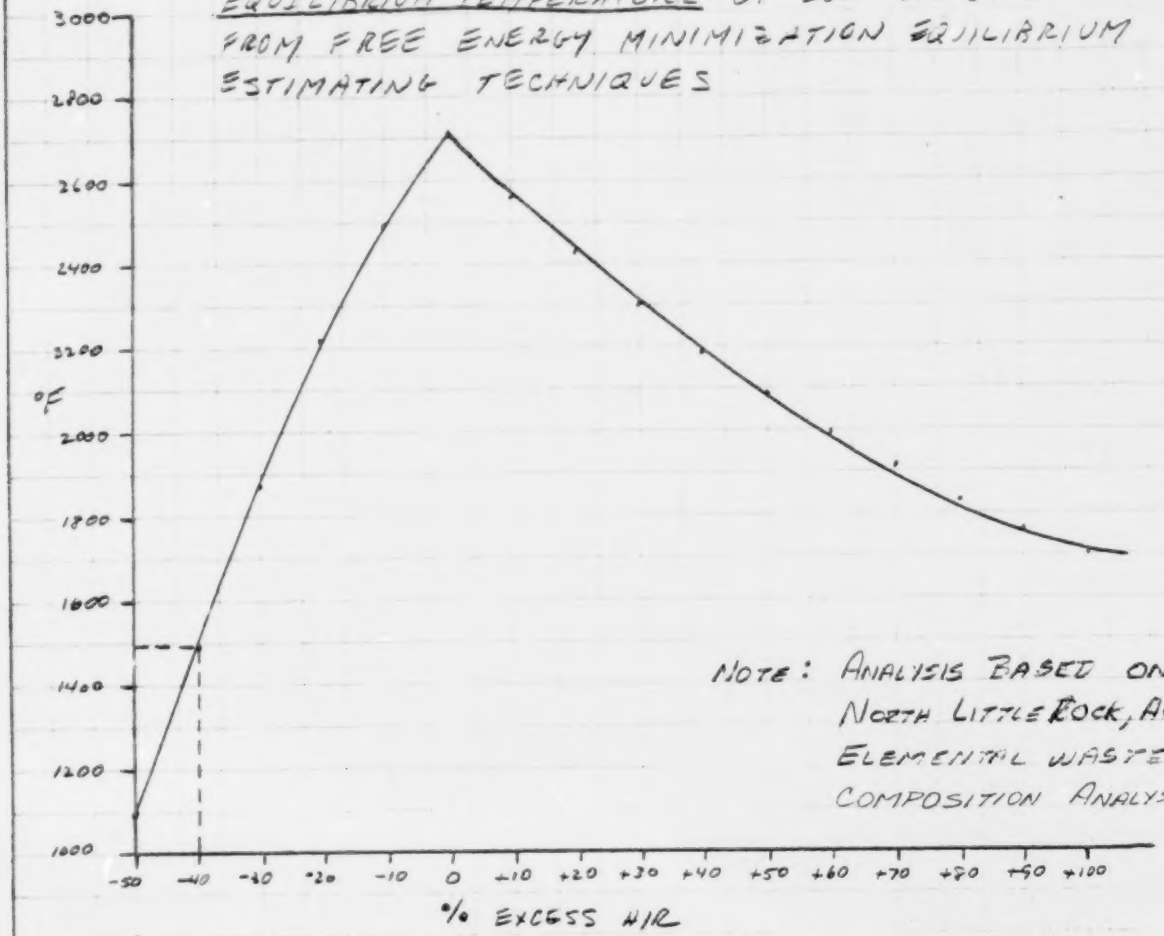
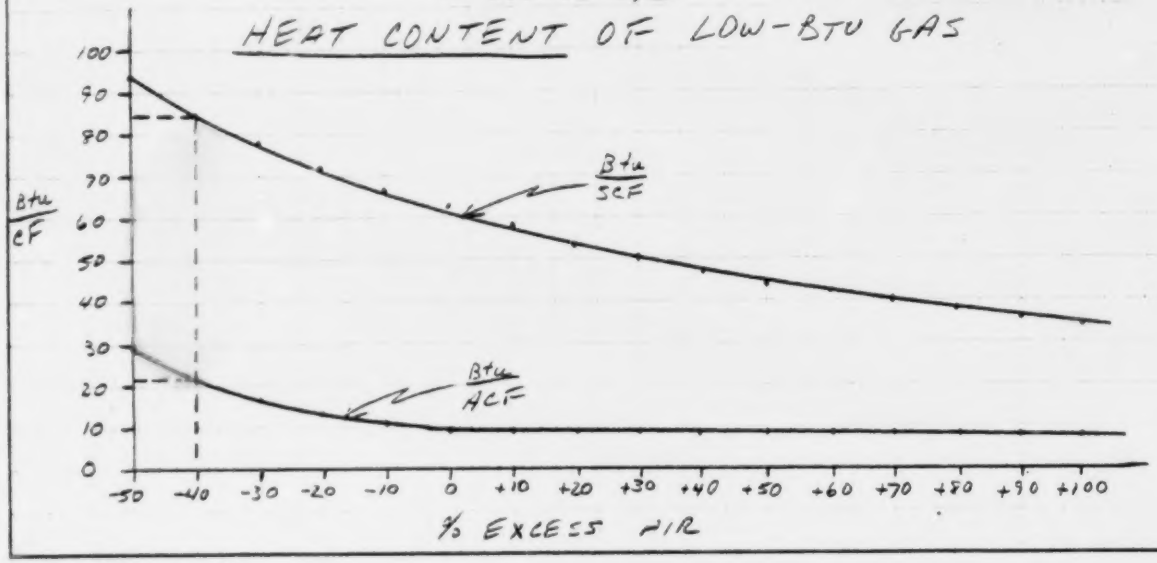
FIGURE 1

EQUILIBRIUM TEMPERATURE OF LOW-BTU GAS FROM FREE ENERGY MINIMIZATION EQUILIBRIUM ESTIMATING TECHNIQUES



NOTE: ANALYSIS BASED ON NORTH LITTLE ROCK, AR ELEMENTAL WASTE COMPOSITION ANALYSIS

HEAT CONTENT OF LOW-BTU GAS



PRODUCT 204-1 VERA Inc. Groton, Mass. 01450

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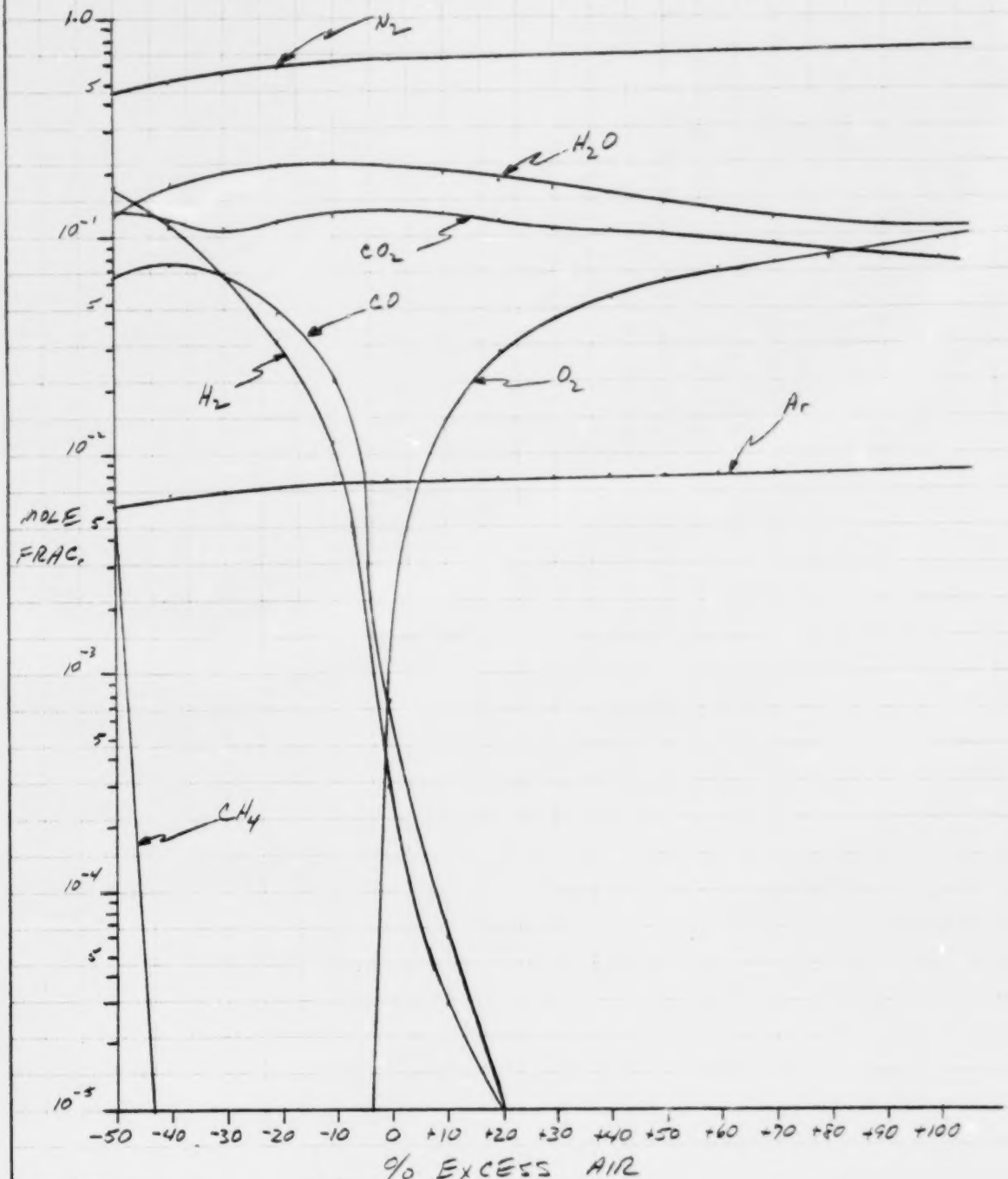
FIGURE 2 - EQUILIBRIUM COMPOSITION OF LOW-BTU GAS FROM FREE ENERGY MINIMIZATION EQUILIBRIUM ESTIMATING TECHNIQUES.



PRODUCT 204-1 NEBB Inc. Groton, Mass. 01450

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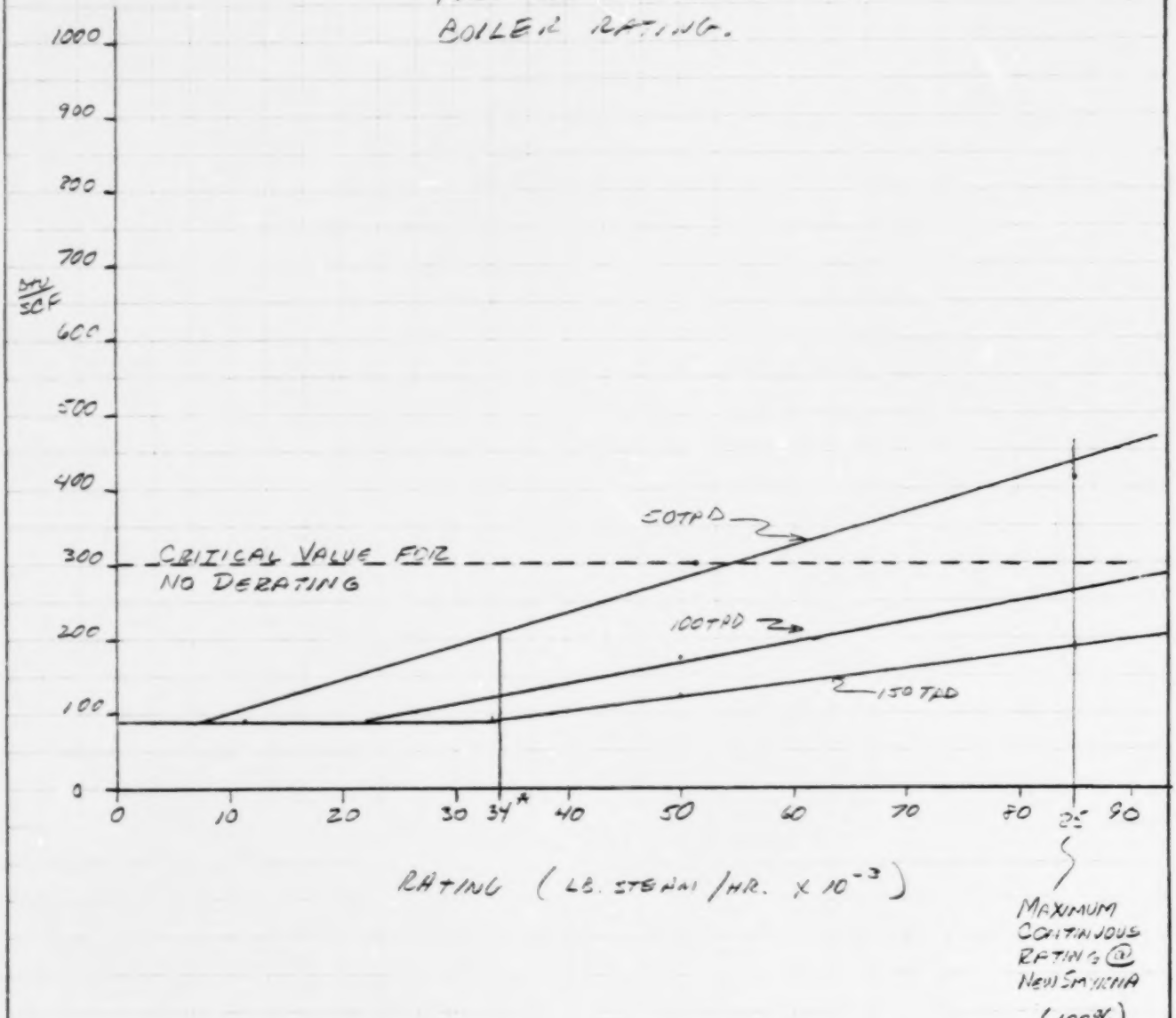
FIGURE 3 - HEAT CONTENT OF LOW-BTU GAS/NATURAL GAS MIXTURE AS A FUNCTION OF BOILER RATING.



* 40% RATING

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in the boiler if low-Btu hot gas were supplied by a 50-TPD_7, 100-TPD_7, or a 150-TPD_7 MCU system. To determine heat content in relation to boiler rating, the steam-raising capabilities of the Swoope boiler burning 100-percent low-Btu gas with a heat content of 90 Btu per SCF were first calculated. These capabilities correspond to approximately 13, 26, and 39 percent of the maximum boiler rating for the average output of the 50-, 100-, and 150-TPD_7 MCU systems, respectively. Above approximately 65 percent of the boiler's maximum continuous rating (about 55,000 pounds of steam per hour), a mixture of natural gas and the low-Btu gas produced by a 50-TPD_7 MCU would exceed 300 Btu SCF. Hence, a 50-TPD_7 system could probably be operated without derating the boiler. However, to utilize the gas produced by a 100- or 150-TPD_7 MCU, the boiler at the W.E. Swoope Plant would have to be derated from the maximum continuous rating of 85,000 pounds per hour, because the heat content of the gas mixture would be less than 300 Btu SCF.

2. TECHNICAL FEASIBILITY OF SUPERHEATING SATURATED STEAM

In this alternative, saturated steam raised by an MCU would be piped to the existing boiler at the W.E. Swoope Steam Plant, to be superheated and directed into the steam plant's existing turbine-generator. This alternative offers capital cost advantages by using the superheater of the existing boiler and the existing turbine-generator, rather than installing entirely new capital equipment, as would be required in Alternative 3.

Conditions for Use

As with the previous alternative, the existing boiler must be baseloaded, so that the MCU system can operate continuously to process a continuous flow of waste.

In order to establish the requirements for steam produced by the MCU, it was necessary to determine the conditions under which

saturated steam piped into the existing boiler could be superheated. Discussions with Erie City Boiler Works, the manufacturer of the boiler at the Swoope plant, revealed that the existing boiler does not have adequate space for a new superheater bank to accept steam from the MCU. Instead, the MCU steam must be introduced between the upper boiler drum and the superheater inlet header. Given the superheater line pressure losses and the pressure drop between the MCU and boiler, it was concluded that 700-psig saturated steam is compatible with, and could be introduced into, the existing superheater.

It should be possible for an MCU system to meet this steam pressure requirement. MCUs have successfully raised low-pressure saturated steam (i.e., 100 to 250 psig). The enthalpy of saturated steam at pressures of 700 psig (1,200 Btu per pound) is not substantially different from that of the lower pressure steam currently being produced (1,190 Btu per pound). The temperature of the high-pressure steam (505 F) is well within the capabilities of a state-of-the-art waste-fired waste heat recovery boiler. Hence, an MCU is most likely capable of producing the moderate-pressure saturated steam required.

Erie City Boiler Works indicated that the utility boiler at the Swoope plant should be run at a minimum of 50 percent of rated capacity (42,500 pounds per hour, measured at the superheater outlet) before steam from the MCU can be safely introduced into the superheater. This requirement will prevent tube failures resulting from excessive furnace wall temperatures. Data on the minimum boiler firing rate for supplemental steam introduction and performance calculations for the plant were used to determine steam flow rate as a function of load (see Figure 4). When introducing supplemental steam produced by a 50- or 100-TPD_7 MCU system, the minimum boiler ratings required are 65 percent and 80 percent, respectively.

Also shown in Figure 4 are the required percentage natural gas firing rates when saturated steam is introduced from an MCU. The

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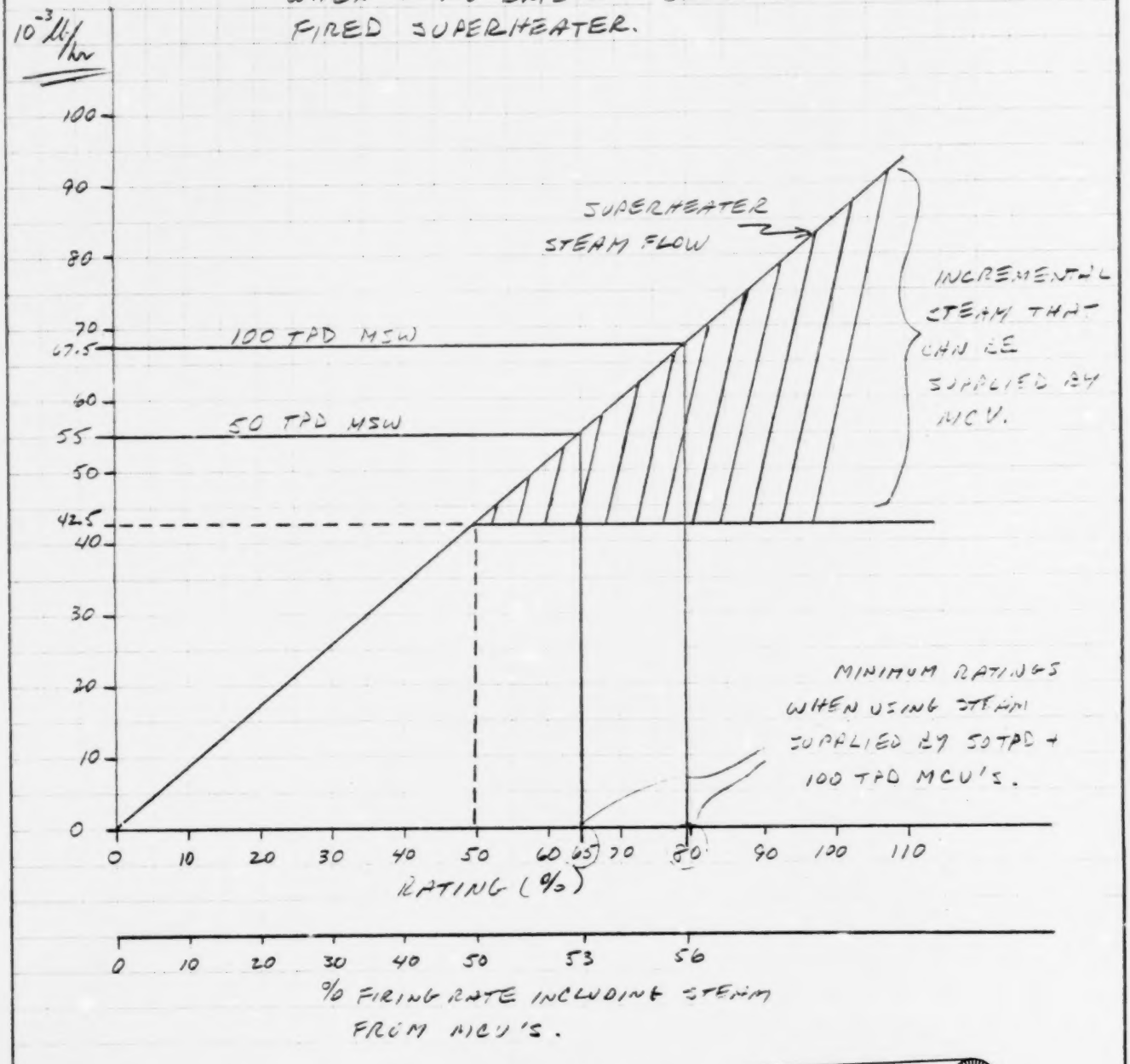
FIGURE 4 - TOTAL STEAM PRODUCTION AS A FUNCTION OF EXISTING BOILER RATING WHEN USING EXISTING BOILER AS FIRED SUPERHEATER.



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firing rate increases linearly with the boiler rating until the supplemental steam is introduced. At that point, each pound of steam introduced by the MCU requires only about 19 percent of the energy that would otherwise be required to raise a pound of superheated steam from boiler feedwater. Hence, for the 50-TPD_7 system, the 3-percent increase in the natural-gas firing rate produces a 15-percent increase in boiler output; for the 100-TPD_7 system, the 6-percent increase in natural-gas firing rate produces a 30-percent increase in boiler output.

Analysis of This Alternative

Producing saturated steam to be superheated in the existing boiler is technically feasible. The MCU system can generate saturated steam of an adequate pressure to be introduced to the superheater of the existing boiler, and use of this saturated steam will increase boiler output.

To satisfy technical requirements and to utilize the continuous flow of saturated steam from the MCU system, the boiler would have to operate continuously at a minimum of 50 percent of capacity. This level of operation does not appear to be practical.

3. TECHNICAL FEASIBILITY OF WASTE-FIRED ELECTRICITY GENERATION

In this alternative, saturated or slightly superheated (dried) steam would be produced in an MCU system, and a low-pressure steam turbine-generator would be constructed to use this steam for electricity generation. This new generating unit would be tied into the existing grid. Because this application of MCU technology is recognized as technically feasible, the evaluation focused on its economic practicality (see Appendix B).

The preliminary evaluation of this alternative assumes that the MCU system would produce saturated steam at 285 psig, with no export to secondary customers. These conditions are similar to those of other systems analyzed in previous studies. A small quantity of steam is extracted from the turbine for use in a feedwater heater;

the remainder of the steam is exhausted at 6" Hg (3 pounds per square inch, atmospheric [psia]).

The system's power production is related to the amount of heat transferred in the boiler. Assuming that (1) the waste had a higher heating value of 4,500 Btu per pound as received; (2) the boiler efficiency were 60 percent; and (3) the system operated 24 hours per day, 5 days per week, the 50-TPD_7 MCU system would produce 561 kW, or 3.5×10^6 kWh per year; the 100-TPD_7 system would produce 1,122 kW, or 7.0×10^6 kWh per year (see Figure 5).

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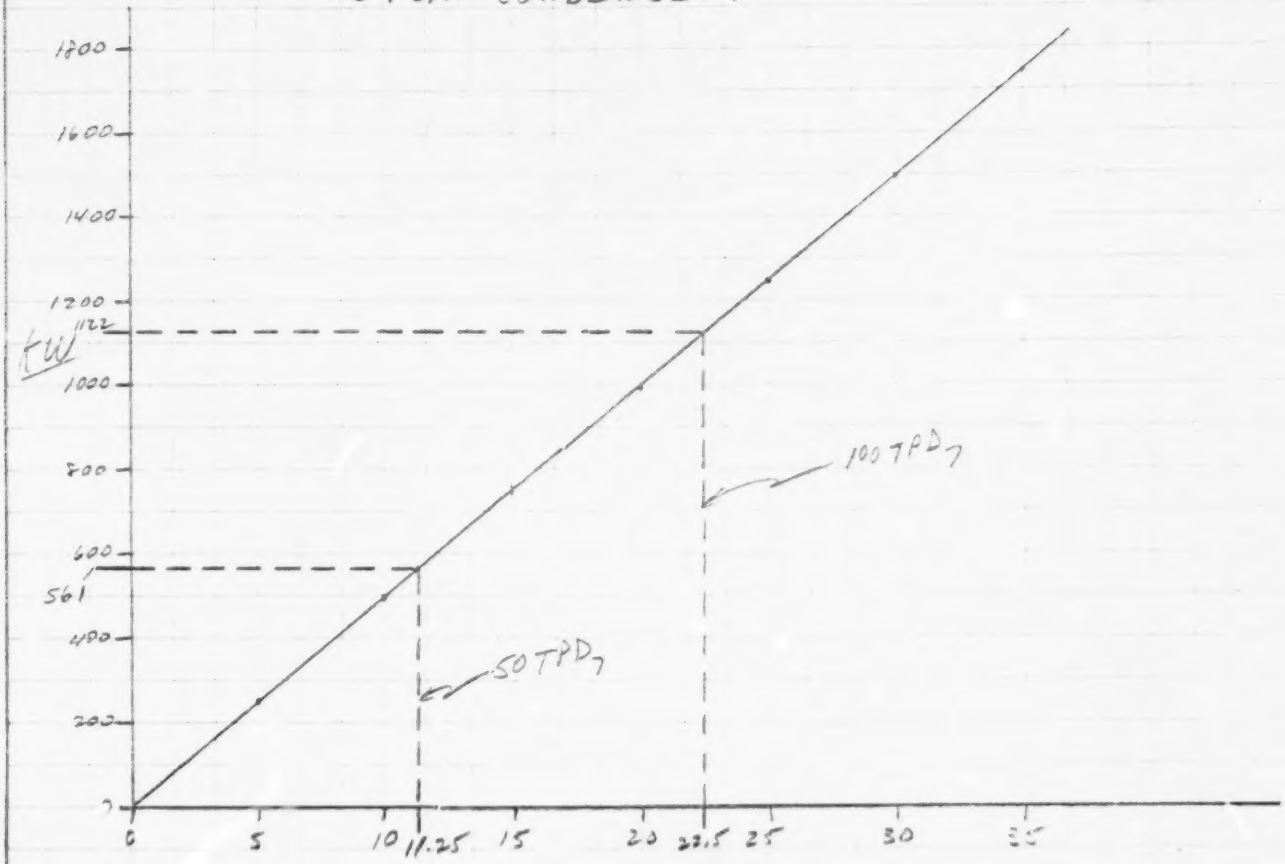
FIGURE 5 - POWER PRODUCTION FOR 300-PSIA WET STEAM TURBINE WITH 3-PSIN CONDENSER.



HEAT TRANSFERRED IN FURNACE - 10^6 Btu/Hr

APPENDIX B.
METHODOLOGY FOR ESTIMATING TIP FEES FOR LOW-BTU HOT GAS SYSTEM AND ORDER-OF-MAGNITUDE ECONOMIC ESTIMATES

In this appendix, the methodology for estimating the tip fees for the low-Btu hot gas system are given, as this is the resource recovery alternative of primary interest to the city. In addition, the results of the preliminary economic assessment are given for the low-Btu hot gas system (Alternative 1) and the MCU system producing steam for use in a new turbine-generator (Alternative 3). As explained earlier, without generating order-of-magnitude economic estimates, it was possible to determine that producing waste-derived saturated steam for superheating in the existing utility boiler (Alternative 2) would require a substantially higher tip fee than the low-Btu gas system. For this reason, no economic estimates are given for Alternative 2 in this appendix.

METHODOLOGY FOR ESTIMATING TIP FEES FOR ALTERNATIVE 1

Three basic steps were involved in the projection of tip fees for the MCU-based low-Btu gasifier system:

1. Make assumptions on all variables involved in the equations.
2. Calculate the value of the low-Btu hot gas that the utility can afford to pay.
3. Calculate the net cost of disposal using the value of the low-Btu hot gas as a credit to resource recovery capital and disposal costs.

Each of these steps is explained below.

Assumptions

Some of the following engineering and economic parameters are readily available, some must be estimated or projected, while others can be set arbitrarily.

a. Waste stream-related

Processible tons of solid waste (7-day basis)	- TPD_7
Heat content (Btu/ton)	- HHV
Ash and residue generated (% of total TPD_7 input)	- R
Residue haul and disposal cost portion ($/yr)	- LF

b. MCU gasifier-related

Efficiency (Btu in gas, % of Btu input)	- η
Capital cost ($)	- C
Debt Service Factor (% of capital cost amortized each year; based on economic life, interest rate, and method of financing)	- DS
Annual O&M cost ($/yr)	- OM
O&M escalation rate (%)	- I^o
Availability of resource recovery plant (%)	- A_{RR}

c. Power plant-related

Cost of purchased electricity from grid ($/MWh)	- E
Purchased electricity escalation rate (%)	- I^E
Cost of fossil fuel ($/MBtu)	- F
Fossil fuel escalation rate (%)	- I^F
Plant output (MW should be set high enough to maintain boiler stability and to use available low-Btu gas)	- MW
Plant heat rate (Btu/kWh)	- HR
Availability of power plant (%)	- A_p

d. General

Escalation period (years from base year)	- N

Calculate Value of Low-Btu Hot Gas

The value of the low-Btu hot gas is assumed to be the value of the electricity produced (at its cost if it were purchased from the grid), minus the cost of the natural gas burned in the plant. This value is adjusted according to the number of days gas can be sold each year and escalation factors. A low-Btu hot gas energy discount may be assumed, which would tend to make generated power less expensive than purchased power.

a. Daily Low-Btu Gas Yield = DG = $(TPD_7)(HHV)_{LG}$ = (Btu/day)

b. Daily Fuel Required = DF = (MW)(24)(HR) = (Btu/day)

c. Daily Natural Gas = DNG = DF - DG = Btu/day

d. Daily Power Value* = $D\$_p = (MW)(24)(E)(1.0 + I^E)^N$ = $/day

e. Daily Natural Gas Value* = $D\$_{NG} = (DNG)(F)(1.0 + I^F)^N$ = $/day

f. Daily Low-Btu Gas Value* = $D\$_G = D\$_p - D\$_{NG}$ = $/day

g. Annual Low-Btu Gas Value* = $Y\$_G = (D\$_G)(365)(A_{RR})(A_p)$ = $/year.

Calculate Net Cost of Disposal (Tip Fee)

The net annual cost of disposing of wastes in a resource recovery plant is the annual resource recovery plant debt service, plus annual operation and maintenance costs, plus residue and bypassed waste disposal costs, minus credits for low-Btu gas recovered and sold to the utility. These values are adjusted annually according to escalation factors.

a. Annual Disposal Cost = $Y\$_{RR}$

$= (C)(DS) + (OM)(1 + I^\circ)^N +$

$[(365\ TPD_7)(R)(A_{RR})] + [(365\ TPD_7)(1-A_{RR})]\ LF - Y\$_G$

= $/year.

---

* These values are different for each year because of escalation.

b. Tip Fee (per throughput ton) = TF = $\frac{YS_{RR}}{[(TPD_7)(365)(A_{RR})]}$ = $/ton.

Sample Calculations

Assumptions

TPD_7 = 100

HHV = 9×10^6 Btu

R = 0.33

LF = $21

n = 0.8

C = $5,835,000

DS = 0.125

OM (1980) = $764,000

I° = 0.08

A_{RR} = 0.9

E (1983) = $54.50/MWh

I^E = 0.10

F (1983) = $4.57/MBtu

I^F = 0.01

MW = 3 (assumed)

HR = 15,750 Btu/kWh

A_p = 0.95

N (1985) = 2 for energy, 5 for O&M

Low-Btu Gas Value

a. DG = $100(9)\ 10^6\ (0.8) = 720 \times 10^6$ Btu/day

b. DF = $(3)\ 10^3\ (24)\ 15.750 = 1.134 \times 10^6$ Btu/day

c. DNG = $(1{,}134 - 720)\ 10^6 = 414 \times 10^6$ Btu/day

d. $D\$_p = (3)\ 24\ (54.50)\ (1.1)^2 = \$4.748/day$

e. $D\$_{NG} = (414)\ 10^6\ (4.57)(1.1)^2 = \$2,289/day$

f. $D\$_G = \$4,748 - \$2,289 = \$2,459/day$

g. $Y\$_G = \$2,459\ (365)\ 0.9\ (0.95) = \$767,300/year\ (1985).$

Net Cost of Disposal

a. $Y\$_{RR} = \$5,835,000\ (0.125) + (764,000)(1.08)^5$
$+[(365)100\ (0.33)\ 0.9 + (365)\ 100\ (0.1)]\ \$21$
$- \$767,300 = 729,400 + 1,122,600 + 304,400$
$- 767,300$

$Y\$_{RR} = \$1,389,100/year\ (1985)$

b. $TF = \frac{1,389,100}{100(365)0.9} = \$42.29/ton\ (1985)$

ORDER-OF-MAGNITUDE ECONOMIC ESTIMATES

In Tables B1 and B-2, respectively, the estimated economics are given for the low-Btu hot gas system (Alternative 1) and the MCU system producing saturated steam for use in a new low-pressure steam turbine-generator (Alternative 3).

TABLE B-1

ESTIMATED WASTE DISPOSAL COSTS ($/TON) FOR ALTERNATIVE 1 -
LOW-BTU HOT GAS, FAVORABLE ENERGY PRICING CASE

			Existing Disposal System	
50 TPD	1983	1988	1983	1988
Capital Cost	$ 28	$ 28		
Operating and Maintenance Cost	51	74		
Low-Btu Gas Value*	(24)	(40)		
Net Disposal Cost	$ 55	$ 62	$ 19	$ 28
100 TPD				
Capital Cost	$ 22	$ 22		
Operating and Maintenance Cost	38	56		
Low-Btu Gas Value*	(24)	(40)		
Net Disposal Cost	$ 37	$ 38	$ 19	$ 28
150 TPD				
Capital Cost	$ 18	$ 18		
Operating and Maintenance Cost	34	50		
Low-Btu Gas Value*	(24)	(40)		
Net Disposal Cost	$ 28	$ 28	$ 19	$ 28

* Equivalent to value of electricity produced, minus natural gas used to supplement low-Btu gas. Assumes that natural gas prices escalate at the same rate as electricity prices.

TABLE B-2

ESTIMATED WASTE DISPOSAL COSTS ($/TON) FOR ALTERNATIVE 3 -
ELECTRICITY PRODUCTION FROM SATURATED STEAM

			Existing Disposal System	
50 TPD[7]	1983	1988	1983	1988
Capital Cost	$ 32	$ 32		
Operating and Maintenance Cost	58	85		
Electricity Purchase Offset	(14)	(24)		
Net Disposal Cost	$ 76	$ 93	$ 19	$ 28
100 TPD[7]				
Capital Cost	$ 25	$ 25		
Operating and Maintenance Cost	44	65		
Electricity Purchase Offset	(14)	(24)		
Net Disposal Cost	$ 55	$ 66	$ 19	$ 28